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## ABSTRACT

To increase educational productivity and efficiency, educational process goals as well as achievement goals must be considered. Educational process goals are interpreted to include student perceptions of the social environment, creativity, self-concept, participation in extra-curricular activities, and interest in subject matter. Ignoring these perceptions and experiences in favor of traditional goals measured by test scores will decrease motivation and ultimately lower educational achievement. Many Educational experiments and psychological theories of education fail to produce desired educational outcomes because they do not clearly identify, define, and measure educational variables. For example, the Higher Horizons Program in New York attempted to upgrade the educational experience of children from deprived backgrounds by reducing class size to five or six students and adding numerous enrichment factors. Because program directors did not consider factors such as the interaction between family and instructional environments, performance scores on tests were not higher. Considerable research is needed to relate educational policy and practice to productivity of schools. Methodology should consider students' ability and motivation, the quality and quantity of instruction, class social environment, and home environment. (DE)

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## A Theory of Educational Productivity

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Two perennial questions in education are: "What are the ends of education?" and "Do the educational means, that is, the manipulations of the environment, justify the ends?" These philosophical questions concern values, morality, and ethics. Modern psychology and social science raise additional points: "Can the ends and means of education be measured?" and "Do the presumed means in fact cause the ends, and, if so, to what extent or with what degree of effectiveness or productivity?"

Although all these questions are important and incompletely settled, I want to address the last question concerning causality, estimates of relation, and particularly school productivity. On this question, education follows medicine, agriculture, and engineering. The physician wants to know the cure rates of groups of patients subjected to different drugs or treatments and possibly a no-treatment control condition. The agronomist estimates the yield responses to various amounts of fertilizer and rainfall; and process engineers find the effect of control settings on output. After these estimates of causal relation are made, policy can be specified within an explicit, objective, rational framework. The feasible treatment or combination of treatments that maximizes outputs can be recommended. Or, if costs of the treatments and the level of the outcome are known, the least expensive feasible treatment or combination can be identified. Judging from the accumulated research, however, such causal relations and objective policies are not easily identified in education.

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It is by no means clear, for example, that the two chief determinants of school operating expenditures--class size and the usual teacher qualifications such as experience and degree level (on which salaries are based)--are, with other things being equal, consistent and strong determinants--causal determinants--of achievement test scores or other measureable outcomes of education. If not, then policies and decisions with respect to these variables must be based on wisdom, tradition, guesswork, or authority, but not on systematic applied research.

Why is it comparatively difficult to estimate and replicate causal effects in education? Among other factors I would suggest, educators in different classes, schools, and systems often place different emphases on the goals of education. Even when the goals are similar, they employ different means and implementation strategies to accomplish them. Such variations may make comparisons difficult if not arbitrary; moreover, measures of many worthy goals such as integrity and courage are unavailable. Measures of other goals such as creativity and moral development lack adequate reliability and validity and even the goals that are measured reasonably well such as reading and mathematics skills and knowledge of the basic subject such as science, social studies, and English are indicated by a great number of uncalibrated, uncomparable tests. Thus, measurement inadequacy and uncomparability may vitiate the comparisons that we would like to make. Finally, it is often difficult to assign students at random to alternative environments and courses of instruction, and certain quasi-experimental or statistical control procedures are often required for causal or policy inference.

Even given these and other difficulties, however, it seems reasonable in a democratic society to raise questions about productivity of our public agencies, including the schools, rather than placing complete trust in tradition or expert opinion. With respect to productivity, if education is the largest

industry in the United States (involving nearly all the people at some time during their lives and perhaps a quarter to a third at any given time) then even a small improvement in productivity can bring about immense savings, including, by the way, the precious value of human time.

In the 1970's, moreover, public interest in educational productivity and efficiency rose. Time Magazine, last year on November 14, reported that during the period 1962 through 1976 costs per student in the public schools rose from \$400 to \$750 when effects of inflation were removed. But the average scores on the College Entrance Examination and the Scholastic Aptitude Test for national samples fell from 470 to 430 on the Verbal section and from 500 to 470 on the Mathematics section. Newsweek on November 7 also noted the SAT decline and reported for the period 1972 through 1977 that total professional staff in all United States public schools rose 8%, the cost per student rose 21% (with inflation correction) while the number of students and the number of schools each fell 4 per cent. None of what I've said is meant to imply that the SAT scores should be considered the only outcome of interest or that costs per student are the best indication of efficiency. The point is, however, that raising questions about productivity not only seems reasonable but timely.

To determine educational policy and practice requires not only the valuing of certain ends but the assumptions that the means employed cause the ends in question. Experiments with random assignments to treatments are ideally suited to probe or assess causality, but Gilbert, Light, and Mosteller in a recent review were able to find what they considered to be two well-executed field experiments in education. Although the stringency of their criteria might be relaxed to include more experiments, it seems that experiments are difficult to implement in natural settings of education. Two alternatives, quasi-experiments and path analysis, also present difficulties in elucidating causation. Quasi-

experiments in practice usually only control for one or two rival causes as a rule rather than a reasonably complete list of the known correlates of educational achievement, and path analysis or structural equations as employed in behavioral research usually beg causal questions by assuming rather than probing their answers. As a third alternative I believe that when experiments are not feasible, observational, that is to say non-experimental research, studies should include the chief known correlates of educational achievement. These, I believe, are: age or developmental level; ability, including prior achievement; the social environment of learning or the student perception of the class; the quality of instruction; the quantity of instruction, that is the amount of time spent on learning or allocated for learning; and the home environment.

Many psychological theories of education can be subsumed by Kurt Lewin's general formulation of behavior as a function of personality and environment,  $B=f(P,E)$ . Educational researchers have implicitly or explicitly adopted a similar general equation,  $L=F(A,T,E)$ --learning is a function of aptitude and treatment, in which learning is a function of individual aptitudes and the instructional treatments, possibly also including some measures of the environment of the learning situation. But among the problems of these general equations like Lewin's or the one I just mentioned in educational and psychological research are: agreeing on a list of the parts of each of the constructs; operationally defining and measuring each part; stating the rules for adding up the measurements for an overall estimate of each construct, if required; and specifying the form of the equation and estimating its coefficients.

I want to touch on several of these problems but I'm mainly concerned by specifying the form of the equation and applying it to the explanation of several educational production problems. One possible problem of the equation

I just mentioned is that it does not allow for the possible interaction of aptitude and treatment that Lindquist, Cronbach, and Snow have written about. Their contention is that a student with, say, high visual aptitude may benefit more than others from instruction making use of pictures. Such interactions may be tested by using multiplicative terms in the model. Although such interactions seem educationally sensible (because after all they imply a form of individualization), they also in my judgment have been found weak and certainly difficult to replicate--not only because of the variation in constructs and measures but also because of the high correlations of aptitude and environment with the product term.

The notions of interaction, I believe, particularly of aptitudes and treatments, may yet bear fruit but part of the problem seems to lie in the form of the equation. Econometric production functions incorporate such interactions parsimoniously and also suggest other analogues worth attempting to apply in education. People working in econometric analysis often assume that output, that is, either nationally or at the factory level, is a function of capital and labor (sometimes subsuming land under capital for simplicity of illustration). A specific form of this general equation often serves to account extremely well for economic processes that are known to be highly complex. The Nobel prize-winning economist Paul Samuelson showed "how we can sometimes predict exactly how certain quite complicated capital models will behave by treating them as if they had come from a fairly simple production function." The most celebrated function in economics is attributed to Cobb and Douglas. A clear exposition by the two of them and Douglas' replication of its coefficients in various countries and time periods led to its widespread use. Other more complicated production functions by Arrow and others may eventually prove superior but they presently lack the long record of successful empirical verification of the Cobb-Douglas form. The classical Cobb-Douglas function treats

national output or output of a particular factory or industry as a logarithmic function of capital and labor. It has a number of interesting features that I will mention.

First, economists are blessed with such a strong model of production. Even if it can be shown to be clearly wrong, it is explicit and testable. Given only three or four variables that are reasonably well-defined and measured, an explicit form of the equation with only a few coefficients and estimates of the function can be repeated and possibly replicated; and after all, replication is the essence of science. And the results and the forecasts as a matter of academic interest or policy decisions can be expressed in the universal and easily understood language of percentage changes.

Perhaps Lewin's formulation that I mentioned earlier, that is, behavior is a function of personality and environment comes as close to the general production function as any other equation in psychology. If transitional processes such as perception are set aside, Lewin's split of forces within and outside the individual seem reasonable; but psychology has reached very little consensus on the parts of each construct, that is, personality, behavior, and environment. Nor have psychologists reached consensus on the definition, the measurement, the scoring, and the specific, explicit form of the equation.

If we narrow the problem from behavior in general to academic achievement on standardized tests, then a preliminary list of the production factors may be drawn up on the basis of reasonable consistency in predicting variance in achievement. I'd like to mention those six factors again: 1) the child's ability or some pretest, 2) the child's motivation (two characteristics of the individual), 3) quality of instruction (this includes not only teaching but self instruction), 4) quantity of instruction (time allocated, time taken, time assigned), 5) the class social environment or the morale of the group (the extent to which it has constructive social/psychological characteristics, being democratic, cohesive,

goal-directed); 6) the home environment which we find in our own work to be one of the most powerful predictors of school achievement. I'm not talking here, by the way, about social class--I'm talking about a comprehensive measure of the quantity and quality of the parental interactions with the child and encouragement of the child in school. These are more powerful than social class, that is to say, that some families that might be considered poor have extremely constructive home environments; and there are also middle class and professional families that don't spend time with their children to encourage their intellectual and emotional development. (The last factor that may be considered is the child's age level).

Consider the seven production factors with respect to achievement. There is considerable redundancy or co-linearity or correlation among these seven variables. For example, measures of cognitive aptitude and home environment each account for, or are associated with, about 60% of the variance in achievement. Put together they only account for about 80%, suggesting a tremendous overlap between ability and the stimulating qualities of the home environment. Similarly, cognitive aptitude and student perceptions of the classroom environment account for about 90%, so there is also considerable overlap. Generally speaking, a student high on any one of these variables except perhaps age is more likely to be high on the other variables which invokes the biblical injunction "to them that hath shall be given." Children that have higher abilities generally have higher home environments, so there tends to be a high correlation among these variables.

Despite this redundancy, variables in a complete equation would be expected to carry significant weight in achievement regressions, that is, in the explanation of achievement. They should each explain a unique variance in achievement provided that they are reasonably well-measured and vary over a moderate range. In order to detect these relationships we have to have some

reasonable variation among the independent and dependent variables. In hypothetically applying the Cobb-Douglas formulation to the variables I just described, increasing any production factor increases achievement; raise any one of these things and you'll get a return--a benefit to achievement. Increasing any factor while holding the others constant or fixed produces diminishing returns; that is to say, if we keep improving instruction without allowing more time or without changing the home environment or any of the other factors, we will reach not negative returns but each additional amount of effort that we put in will bring a smaller and smaller increment in the child's performance.

A direct extension of the economic production function is that any factor equal to zero results in zero achievement. Unlike capital and labor, however, the educational production factors may not have validly measurable zero points implying a ratio scale. It is more reasonable to hypothesize that when we have problems in measurement, that where any factor is near minimum, it is unlikely that achievement can be high unless all the other factors are at their maximum levels. In other words, if the child's motivation is near zero he can't be very high in achievement. If his ability is near zero, or if he's gotten extremely poor quality of instruction, he can't be high in achievement. Any one of these factors being low would suggest or be associated with extremely low levels of achievement.

Increasing all the factors by a given amount raises the achievement by the same amount. The factors can substitute or trade-off or compensate for one another but again with diminishing rates of return. If to take just quality and quantity we can give the child more and more and more time but unless we simultaneously improve, say, the quality of instruction, that additional time will have diminishing rates of return, very much analogous with the economic laws of diminishing returns. (Again remembering I'm speaking hypotheti-

cally here).

One interesting feature about this function is logarithms are taken of the variables in a very straightforward procedure; if causality can be accepted, and if the production function is found to be a good fit, the coefficients or regression weights suggest the percentage return in achievement by a 1% increase in each any one of the production factors. So it suggests a simple matter of interpretability--raise a factor 1% and you will get a .5% return in achievement. It lends itself to easy interpretability even for the lay public.

I want to mention one other factor here: comparable to time which serves a proxy for technological progress in the production function in economics, age might also serve as an index of maturation. I mention age as a seventh factor. Piaget's work and Stevens' book on spontaneous schooling suggest that learning may occur inexplicably, incidentally, and unintentionally with increasing age; that is, even if you remove the effects of all other factors, children seem to get a little smarter as they get older. So to handle this kind of thing we might consider the child's age or developmental level. Given a wide span of age and a wide measure of achievement, the growth curve for a particular child might turn out to be linear, exponential, or logistic. Presumably if the production factors outside of age were held constant the age term would generate a smooth growth curve. Varying the other factors would produce accelerations or decelerations around this growth curve. It may be further hypothesized that the steady application of the production factors will produce more growth than fits and starts which may be analogous to mass practice which we're familiar with from education psychology.

The seven variables I'm suggesting in this function are known to correlate consistently with academic achievement. It seems educationally plausible to impute causality to them although it would be more defensible to do so after they're analyzed in full concert, or one might say, in competition with

one another because one or more of these may be sufficiently redundant with the others to delete. Moreover, if true experiments cannot be done with random manipulation of the factors then the best possible hope for causal inference is to include all possible causes in the regression.

Now, I'd like to apply this theory to several important educational problems. Take, for example, educational innovations. Many federal and state supported educational innovations that have been evaluated in the last two decades are attempts to change the quality of instruction or teaching and to raise measured educational achievement on standard tests. Since the quality of instruction is only one of the six production factors and the other five may remain unchanged, diminishing marginal returns would ensue. Or other production factors may systematically explain some of the variations. Whatever the case, it does seem to be that some of the major evaluations that have been conducted have been extremely discouraging. They seem to suggest that improving teaching or improving the curriculum will not affect test scores very much. "Why should this occur?" I might derive from production theory at least ten reasons for it:

1. Volunteers who have nearly maximized their teaching participate in these experiments; therefore, the additional increased returns are too small to be detectable. In other words, when you start out with better teachers to begin with (as many of these innovations do) they can't improve all that much more; they're running up against some sort of ceiling.
2. Untransformed linear terms are used to fit what I would consider more plausible, the curved logarithmic relationship suggesting marginal

diminishing returns.

3. The sample is drawn from a single school district relatively homogeneous in quality even after the innovation; therefore, the increment in achievement with respect to a small change in quality is undetectable. In other words, the two treatment groups may differ but they differ by such small effect that we cannot detect that effect on achievement.
4. The other five production factors are unmeasured and are not brought into the equation; therefore, the dependent measure would be given five large random shocks resulting in a scatter of points that make the true returns to quality undetectable. In other words, if you don't have the precision suggested by a full set of variables you may not detect a subtle or smaller effect with respect to increased quality of teaching.
5. Two large random shocks due to measurement error of achievement and quality of instruction to any data point obscure the relation of achievement to quality. We know that measurement error either in the dependent or independent variable attenuates those relationships; so this could also lead to a partial explanation of why we have been seemingly unsuccessful at explaining why innovations have not caused increased achievement.

6. Only aptitude and quality are typically included in the analysis. Quality only adds 3% to the 60% of the achievement variance explained by aptitude; and the variance increment approach underestimates the true returns of teacher quality.
7. The innovation and control groups overlap substantially in teaching quality. A nominal two group categorization rather than a continuous measure, and I might say, reliable measure of implemented quality is made, therefore obscuring the relationship.
8. The so-called non-innovative control teachers compete with the innovators by assigning a greater quantity of time to instruction during the subject unit; and if this is not considered, it would obscure the relationship and suggest that the innovation had no beneficial effects.
9. Students in the non-innovative control group compete with their peers by doing more homework, and the analyst fails to consider time allowed for self-instruction.
10. The quality of teaching index contains a mix of elements most of which previous research has not shown to be productive of achievement.

These points are overlapping and concern design, measurement, and specification problems that in various combinations are sufficient to vitiate field

evaluation research. A more reasonable evaluation of the innovations and also a probe of the production theory would include reasonably complete representation of the production factors, valid measures of each, sufficient variation in instructional quality and other factors and logarithmic transforms in accord with the hypothesized function to account for the diminishing marginal-returns curvature and the multiplicative interaction (or substitution trade-off or compensation as you might want to call it) between these various factors.

Now I'd like to turn to another educational problem that has gotten a lot of interest in recent research literature and review literature and one that we're conducting a review on right now in our own staff at the University of Illinois: quantity of instruction (or time allocated or time assigned or the amount of time the student takes). Many of us are familiar with the formulations of Bloom and Carroll that have emphasized the importance of time. Time scheduled, allowed, assigned, or taken for a given instructional unit by the teacher, or better yet, the fraction of this time the student actually engages in learning unit content is turning out to be a moderately consistent though apparently weak correlate of academic achievement.

Our review suggests that the correlations here are not going to be of the order of .9, but they're going to be a steady .2 to .3; that is, the correlation of time with the output measures is small but fairly consistent across a great number of studies in a variety of dependent variables including language learning, religiosity, and of course, school achievement. The usual problems of operational definition, measurement, and the lack of factor variation may account for the small correlations. But the production function suggests that mis-specification of the equation may also be a problem. Bringing more of the production factors into the equation, finding data in which time varies over a greater range, and taking logs may help considerably.

One of the problems of research on time is if you go into a natural setting you may find that it doesn't vary very much; and since something doesn't vary, it can't **covary** with another factor. So part of the problem is a design difficulty.

In connection with time a methodological point may be made. Bloom estimates that the slowest 10% of the students may need five to six times as much time to learn as the most rapid 10%. Rarely are such large ratios encountered for variables in educational research. The typical variables that we deal with don't vary over much of a range. In a typical school class, for example, the highest and lowest IQ's might be 120 and 80. The extreme scores on a 50-item achievement test might be 45 and 30. Both of these ratios are 1.5:1--certainly not of the size of 6:1. As emphasized in some of my earlier remarks here, educational measurements are severely limited in their range and reliability. Even so, when achievement is related to time, the regressions when they are tested (and often they are not tested; simple linearity is assumed) often the regressions turn out to have diminishing returns.

Swimming is a sport that provides a precise additional example. Colonel Ransom Arthur shows that at a thousand yards a day, one reaches 75% of one's maximum training effort. At 2,000 yards (that is, doubling it) you only get up to 85%. In order to get to 95% of your maximum effort, which is basically an aerobic or lung conditioning sport, one needs to go 10,000 yards a day in training; and to get 99 to 100% of your maximum performance would take 16,000 yards which, for me, would be 4 hours. So you can see a great sacrifice in time--more and more time leads to smaller and smaller returns. Not only with respect to apparently academic achievement, computer-assisted instruction, but other factors that we've looked into. Although such things and others such as ballet, music, chess, science, and writing performance cannot be measured so precisely, they appear to show diminishing returns relative to time. Good

or even excellent performance by the usual standards may only require a half hour or an hour a day of concentrated effort. But national or international rankings (or one might say, one's best) may require, among other things, three to ten hours a day of instruction and practice. I want to also acknowledge the fact that if you have too much time you can get not only diminishing returns but negative returns. Pushing past an uncertain point may kill motivation.

Now I'd like to turn to compensatory education--certainly an important and controversial topic. During the 1960's some policy makers and educational practitioners appeared to believe that better educational practice can completely compensate for social and family disadvantages in the determination of achievement. Although this conception was somewhat vague, it often seemed to imply or amount to the hypothesis of a linear trade-off between family and instructional environments. Such expectations resulted in frustration because the returns to achievement, to real increases in educational expenditures and apparent improvements in schooling seem to be by no means linear. Some even concluded that marginal returns might even be zero. A good example of this is the Higher Horizons Program in New York which trebled the cost of education--reduced class sizes to five and six, and yet there were little or no differences in the test performance.

By the standards of the production function, however, I would argue that adequate evidence and analyses of the returns are still yet unavailable. Home environment was indicated by socio-economic status, family size, ethnicity, objects in the home, and other sociological, anthropological, or psychological variables rather than the more educationally relevant amount and intensity of adult-child interactions that accounts for several times as much variance in achievement. In addition, the reviews of Rosenshine and others on the production factors in teaching that indicate predictively valid constructs were ig-

nored. Because of poor measurement and the lack of evidence on the other production factors, the returns to compensatory programs have been very poorly estimated. Moreover, the returns to quality, although expected to be positive, are expected to be diminishing rather than linear.

Aside from the apriori postulate of the production function that calls for such returns, evidence on the achievement fan spread of individuals and the increasing gap of groups over time supports the hypothesized relationship. If you know Campbell and Cooke's new chapter on experiments and quasi-experiments in the Handbook of Industrial and Organizational Research, in discussing the various quasi-experimental designs they show evidence that in educational programs for the disadvantaged the relatively rich often get richer, that is, that students who are higher in achievement benefit more from the program than do those who are lower in achievement. The Sesame Street evaluation re-analysis of the ETS study by Cooke was a good example of this. It showed that Sesame Street conferred a greater achievement benefit to advantaged groups rather than those for whom it was intended, and thereby increased rather than reduced the gap as it was intended to do.

The production function predicts precisely such phenomena. The higher any factor becomes for all students, the smaller are its marginal returns and the greater the weight and the relative determination of achievement by the other factors. Conversely, the lower the relative level of a production factor, the greater are its marginal returns and the more promising it would be to change provided that budgets and social and political factors would allow it.

Just to put a gloss on the Cooke analysis, he found in further analysis of the data that parents from more stimulating homes would not just let the child watch (or encourage the child to watch) Sesame Street, but also discuss it with the child so that often the advantaged children benefited considerably

more. The fact that measures of the home environment account for about 60% of the variance in achievement (not social class, but home environment as I've defined it here) suggests that many students would achieve considerably more if the amounts and intensity of intellectual stimulation in the home environments were increased.

Indeed, two field studies of school programs that were intended to help parents in highly disadvantaged neighborhoods to stimulate their children at home show that achievement gains can be doubled over comparable control students at least over a six to twelve month period. These two programs cost very little and were met with enthusiasm by parents. Further investigation of these programs over longer periods of time using the production function may bear out the promise of the initial field studies. These would obviously be susceptible to Hawthorne effects, and they may not be sustained and so on, but I do believe that they are promising.

In conclusion, I'd like to mention several points. The educational production function theory appears to explain some important phenomena concerning the relation of test achievement to the production factors. The best probe or validation of this function would require longitudinal data on all seven factors and a wide-range achievement test that reflects the curriculum content. Data at only one or two time points or on only some of the factors or on somewhat unreliable rather than optimal measures may also prove valuable in partially testing the function.

All I'm claiming here is that this function seems plausible and reasonable; but more than that, it's explicit. Since it's explicit, it's testable; it can be proved to be wrong. Should the production function survive tests, replicated values of the coefficients might be used to stimulate and forecast the effects of changes. Given cost estimates of each one of these factors and acceptability of the changes, the best strategy for policy-making could be

derived from it in reaching achievement goals.

Even so, I want to soften my earlier emphasis on academic achievement. Production theory offers caution in attempting to maximize only one output. Despite the numerous ability and achievement tests available they tend to measure only one major factor--verbal educational accomplishment--surely an important aspect of human quality but by no means the only one.

Performance on such tests predicts subsequent grades and performance on similar tests. For samples of adults, however, that have attained the same amount of education in number of years, neither test scores nor grades accurately predict indicators of success in later life such as income, participation in community activities, self-concept, supervisor and peer-rated effectiveness on the job, the number of prizes, written works, patents, and other accomplishments. Or at least if they do it's a very weak relationship. Several reviews in this area suggest that with a homogeneous sample of, say, physicians or teachers, one would generally find that grades and test scores don't correlate with indices of adult success. What does? Engagement in independent, self-sustained ventures and extracurricular activities during the high school and college years often forecast such forms of adult success.

How much effort should be given to the production of test achievement? The law of increasing relative costs in economics states that to produce equal amounts of one good (other things being equal) larger and larger amounts of other goods must be sacrificed. Thus in setting achievement goals on the usual tests and the earliest or most effective or most cost efficient or rapid means of attaining these goals, educators, parents, and students should consider the extent to which other goals, opportunities, or experiences--valuable for the present or for the future--must be sacrificed. The causal mechanism and the costs and benefits of other goals and their trade-offs with test achievement cannot be accurately measured. However, measures of the student perception of the social environment, their classroom experience

such as its difficulty level, its cohesiveness, its goal direction, its democracy, and other social-psychological properties not only provide demonstratedly valid indicators of a production factor but also an additional educational process goal in their own right as a balance against tests scores alone. Additional productivity research on such variables is obviously in order and might contribute much to educational wisdom.

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